Volatility Spillovers of Fed and ECB Balance Sheet Expansions to Emerging Market Economies*

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Abstract

This paper examines volatility spillovers from the expansion of the balance sheets of the Federal Reserve (Fed) and European Central Bank (ECB) to emerging market economies. Using a GARCH methodology over the period 2003 to 2014, we find that volatility spillovers due to the expansion of the Fed balance sheet to emerging market economies have been much more pronounced and far-reaching than volatility spillovers from the the expansion of the ECB balance sheet. In particular, ECB volatility spillovers to emerging economies are confined mainly to bond spreads and the bilateral euro exchange rate. On the other hand, the Fed volatility spillovers are greater in magnitude across financial variables in emerging market economies and also affect the volatility in industrial production in some of these countries.

JEL Classification: F3, F4, F16, G1

Keywords: unconventional monetary policy, central bank balance sheets, volatility spillovers, financial markets

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Non-technical summary

This paper examines volatility spillovers from expansions in the balance sheets of the Federal Reserve and the European Central Bank over the period 2003 to 2014. Since the announcement of the Federal Reserve's (Fed) intention to slow its monetary stimulus, emerging markets' currencies and asset prices have become volatile. Recent literature has concentrated on the effects of unconventional monetary policies in developed countries and their spillovers to developing countries focusing on the increase of major central banks balance sheets and their effects on the levels of financial variables in other countries. However, the volatility that has been observed in the financial and real variables in many developing countries has largely been ignored. The recent end on the one hand of unconventional monetary policies in the U.S., and the decision of the European Central Bank (ECB) to embark on quantitative easing on the other, has renewed interest in the volatility spillover from these policies to emerging market economies. The expansion of both the Fed and the ECB balance sheet since the crisis has been significant and has likely encouraged outflows from their respective economies to other countries especially emerging markets, where interest rates remained significantly higher.

We explore how much the expansion of the Fed and ECB balance sheets can explain volatility of variables in emerging market economies. We find that the volatility in the Fed and ECB balance sheet can explain part of the volatility in emerging market economies financial and macroeconomic variables. We explore the dual transmission channel of monetary policy to domestic economies and spillovers to emerging market countries using a two-step specification to measure volatility spillovers to emerging market economies. We investigate the volatility spillovers from the unconventional monetary policies of the Fed and the ECB while most of the recent literature investigates the level spillovers. We explore the volatility spillover from the increase in the ECB and Fed's balance sheet to bilateral exchange rates, stock and bond markets and macroeconomic variables such as inflation and industrial production. Our goal is to measure the volatility of economic and financial variables in emerging market economies that can be explained by the volatility spillover from the balance sheets of the Fed and the ECB. We also attempt to make some inferences regarding the impact of an exit from unconventional policies.

We examine the effects of monetary policies in the U.S. and the Eurozone measured by the change in their respective central bank balance sheet, and the spillovers of these policies to the volatility of the financial and macroeconomic variables of Brazil, Russia, India, China and South Africa, Poland, Hungary, Croatia, the Czech Republic, Colombia, Chile, Mexico and Peru. The expansion of international trade and a more pronounced increase in cross-border capital flows means that countries are more interconnected with developing countries receiving and sending substantial amounts of capital. The recent crisis has reversed some of these capital flows to and from emerging market economies and has increased volatility in both macroeconomic and financial variables. The unprecedented actions by major central banks, which can affect the 'world' interest rate, are likely to have had an impact on the volatility of financial and macroeconomic variables in emerging markets. We measure volatility spillovers from monetary policies as the

volatility in emerging market financial and macroeconomic variables that can be explained by the volatility in the Fed and ECB balance sheets.

1 Introduction

> '...frankly the ECB has not done anything to increase volatility in the markets. If you think that the ECB has done anything that is comparable to what is happening in the other central banks, we would not agree with this perception...But, certainly, we have observed an increase in global volatility, coming from major monetary policy decisions or announcements of decisions that may be taken in the coming months. However, I do not think that the ECB has in any way been a source of this; I cannot really find any data to support this.' (Mario Draghi, June 2013)[1]

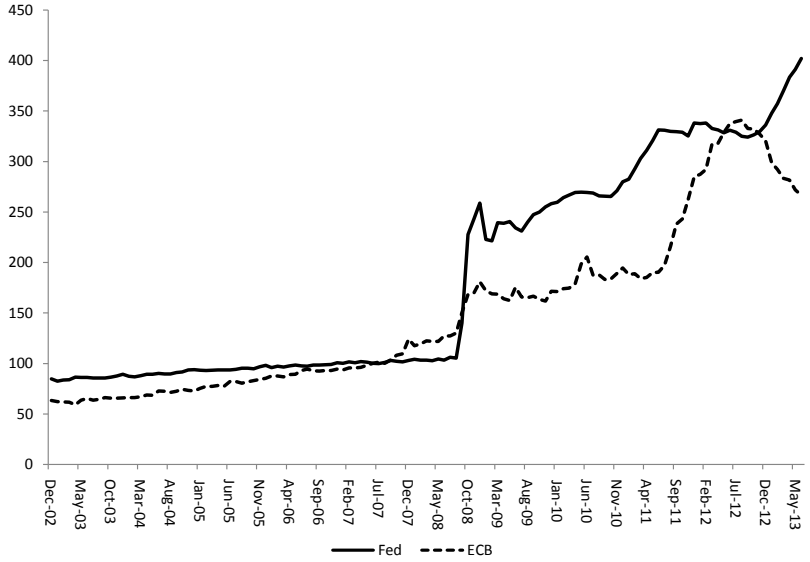
Since the announcement of the Federal Reserve's (Fed) intention to slow its monetary stimulus, in May, 2013, emerging markets' currencies and asset prices have become volatile. Recent literature has concentrated on the effects of unconventional monetary policies in developed countries and their spillovers to developing countries, focusing on the increase of major central banks balance sheets and their effects on the levels of financial variables in other countries. However, the volatility that has been observed in the financial and real variables in many developing countries has largely been ignored. The recent end, on the one hand, of unconventional monetary policies in the U.S., and the decision of the European Central Bank (ECB) to embark on quantitative easing on the other, has renewed interest in the volatility spillover from these policies to emerging market economies. Figure 1 shows that the expansion of both the Fed and the ECB balance sheet since the crisis has been significant and has likely encouraged outflows from their respective economies to other countries especially emerging markets, where interest rates remained significantly higher. We explore how much the expansion of the Fed and ECB balance sheets can explain volatility of variables in emerging market economies.

We find that the volatility in the Fed and ECB balance sheet can explain part of the volatility in emerging market economies financial and macroeconomic variables. Volatility spillovers due to the expansion of the Fed balance sheet to emerging market economies have been much more pronounced and far-reaching than volatility spillovers from the the expansion of the ECB balance sheet. In particular, ECB volatility spillovers to emerging economies are confined mainly to bond spreads and the bilateral exchange rate. On the other hand, the Fed volatility spillovers are greater in magnitude across financial variables in emerging market eocnomies and also affect the volatility in industrial production in some of these countries. Volatility spillovers from the ECB and the Fed were generally more pronounced during the peak of the crisis in late 2008. Volatility spillovers from the Fed have been diminishing since late 2008, despite its exit from unconventional monetary policies but have not diminished as drastically for the ECB.

We explore the dual transmission channel of monetary policy to domestic economies and spillovers to emerging market countries using a two step specification to measure volatility spillovers to emerging market economies. We investigate the *volatility* spillovers from the unconventional

[1] Mario Draghi, President of the ECB, Introductory statement to the press conference (with Q&A), Frankfurt am Main, 6 June 2013

Figure 1: Scaled Assets of the Fed and the ECB (June 2007=100)

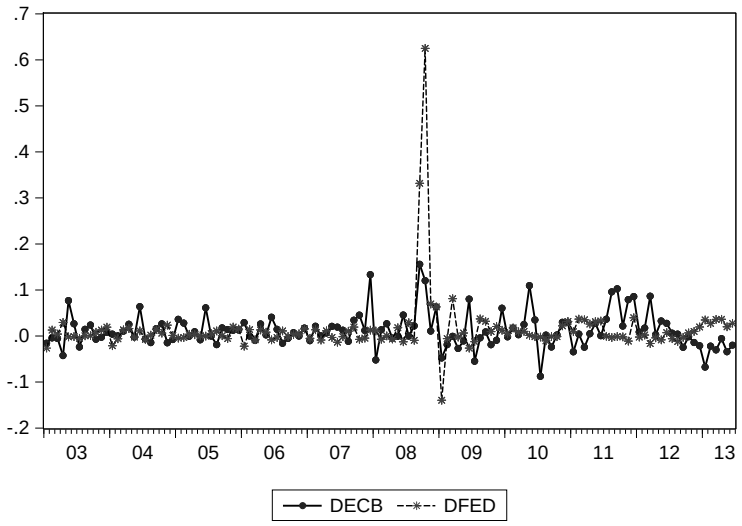


Data:FRED

monetary policies of the Fed and the ECB, while most of the recent literature investigates the *level* spillovers such as Fratzscher, Lo Duca and Straub (2013). They find that the actual purchases of the Fed relating to the change in its balance sheets had an effect on the level of financial variables. We explore the volatility spillover from the increase in the ECB and Fed's balance sheet to bilateral exchange rates, stock and bond markets and macroeconomic variables such as inflation and industrial production. Our goal is to measure the volatility of economic and financial variables in emerging market economies that can be explained by the volatility spillover from the balance sheets of the Fed and the ECB. We also attempt to make some inferences regarding the impact of an exit from unconventional policies.

We examine the effects of monetary policies in the U.S. and the euro area measured by the change in their respective central bank balance sheet, and the spillovers of these policies to the volatility of the financial and macroeconomic variables of Brazil, Russia, India, China and South Africa, Poland, Hungary, Croatia, the Czech Republic, Colombia, Chile, Mexico and Peru. The expansion of international trade and a more pronounced increase in cross-border capital flows means that countries are more interconnected with developing countries receiving and sending substantial amounts of capital. The recent crisis has reversed some of these capital flows to and from emerging market economies and has increased volatility in both macroeconomic and financial variables. The unprecedented actions by major central banks, which can affect the 'world' interest rate, are likely to have had an impact on the volatility of financial and macroeconomic variables in emerging markets. We measure volatility spillovers from monetary policies as the volatility in emerging market financial and macroeconomic variables that can be explained by

Figure 2: Changes in the Fed and the ECB's balance sheets



the volatility in the Fed and ECB balance sheets.

The actions of the Fed and the ECB are of particular importance not only because of the size of their respective economies, and the size of their balance sheets, but also because of the international role of the U.S. dollar and the euro, and their influence on international interest rates. Given the volume of trade and the significant current account surpluses and deficits in a much more globalized world, combined with the activist stance of major central banks the issue of volatility spillovers from monetary policies has come to the forefront of international policy discussions. The recent exit of the Fed from unconventional policies has coincided with volatility in exchange rates, macroeconomic variables and in various asset classes.The turmoil following the May 2013 announcement of 'tapering' of unconventional monetary policies by the Fed and the market reactions after the ECB's quantitative easing programme announcement shows that central banks remain important players in international markets even at the zero lower bound.

The impact of unconventional monetary policies has come to the forefront of policy discussions mainly for two reasons. First, the world economy is more interconnected than ever before, evidenced by the significant increase in the trade linkages of developed and developing countries and second, the increase in foreign reserves held by emerging market countries and the substantial cross border asset holdings and capital flows. Most foreign reserves are denominated in major currencies such as the U.S. dollar, the euro and, to a lesser extent the British Pound, the Swiss Franc and the Japanese Yen, because these currencies are considered to be safe and liquid. The countries issuing these currencies are the most financially developed countries and therefore have attracted most of these foreign reserves. The recent crisis and the fall in asset prices, have prompted central banks in these countries to take unprecedented measures that

are likely to have had an impact beyond exchange rates, to affect the prices of assets held by emerging market central banks and private individuals. The interventions by central banks can probably explain part of the observed volatility of assets and may have pushed investors to other classes thereby affecting portfolio allocation decisions.

The increase in international trade and output linkages between developed and emerging countries has led comovements of output during the crisis. Nevertheless, the growth differentials among countries are noticeable. Therefore, central banks in the countries where growth is rising such as the U.S. and U.K have tended towards monetary policy normalization while other central banks such as the ECB and Bank of Japan (BOJ) have expanded or promised to expand their balance sheets. This unsynchronized policies are likely to affect volatility in the global economy. During the crisis, however, almost all major central banks expanded their balance sheets to stimulate their economies and intervened in asset markets. Yet, growth and interest rate disparities continue between emerging market economies and developed countries and likely loose monetary policies in developed countries can explain part of the volatility in emerging markets variables. The interventions by the Fed and ECB can be seen by the change in the size of their balance sheet, which has been volatile as shown in Figure 2, because central banks changed their policies and the size of their balance sheets as information about the state of their economies became known.

The rest of the paper is structured as follows. Section 2 reviews the related literature that guides the analysis. Section 3 provides the theoretical underpinnings and quantitative evidence of our empirical methodology. Section 4 presents the empirical methodology and the data used and Section 5 summarizes the results. Section 6 provides some policy implications and Section 7 concludes.

2 Related literature

Bernanke and Reinhart (2004) discuss the policy options for central banks, when the zero lower bound is reached. They advocate three main responses to the zero lower bound, one forward guidance for low interest rates, two, changing the central bank balance sheet composition and, three, expanding the central bank balance sheet or quantitative easing. Bernanke and Reinhart (2004), wrote their paper in 2004 and had in mind the chronic problems and very low interest rates in the Japanese economy. Soon afterwards Bernanke became Chairman of the Fed and had to move beyond the academic discussion about unconventional monetary policies and implement all of these policies and then invent new ones to stimulate the U.S. economy, as the Fed quickly reached the zero lower bound. The literature before the crisis made little mention of the spillovers from one country to another because of unconventional monetary policies at or close to the zero lower bound. These unconventional monetary policies however, are likely to have

unintended consequences beyond the domestic economy, and spillover into other economies.

We build on the findings of Fratzscher, Lo Duca and Straub (2013), who find that the Fed's unconventional monetary policy announcements had a smaller effect than the actual operations of the Fed. The authors find that the actual operations of the Fed, which increased its balance sheet, affected the portfolio decisions and asset prices outside the U.S., and spilled over to emerging market economies. Their findings suggest that investors did not fully price in the Fed's announcements and its operations are the ones that had the dominant effect on investors reactions. The authors argue that announcements are not enough to repair dysfunctional markets and that the Fed's actual operations could contain new information that induce investors to change their behavior. The authors argue that the unconventional monetary policy actions of the ECB had similar effects as the actions of the Fed, specifically the 3-year longterm refinancing operations (LTROs) in 2011 and 2012, where the amounts borrowed by the banks were the determinants of the success of the policy. We build on Fratzscher, Lo Duca and Straub (2013) and take the assets in the balance sheet of the Fed and the ECB as the main instrument for monetary policy spillovers.

The recent theoretical literature has developed models on the interconnectedness of countries financial assets such as the model developed by Devereux and Yetman (2010). Their paper proposes a model of the international transmission of shocks due to interdependent portfolio holdings among leverage-constrained investors. When the leverage constraints bind, the diversified portfolios of investors create a financial transmission channel that results in a positive comovement of production, independently of the size of international trade linkages. Related to the recent crisis Bacchetta, Tille and Van Wincoop (2012), proposed an explanation for risk panics based on self-fulfilling shifts in risk made possible by a negative link between current asset prices and risks for future asset prices. The theoretical strand of the unconventional monetary policy literature, such as Gertler and Karadi (2011), finds that indeed there are welfare benefits from unconventional monetary policies. Gertler and Karadi (2011) show that during a crisis, when private balance sheets are constrained, the intervention of the central banks, using its unconstrained balance sheet can deliver welfare benefits.

This literature is closely related to the spillovers from unconventional monetary policy interventions because interventions reduce the risk of future asset prices and thus tend to increase the price of assets today. Regarding asset pricing the CAPM has provided the theoretical background for pricing risky assets. The basis of most asset pricing methods is the papers by Sharpe (1964), Lintner (1965) and Merton (1973). However, the reduction in the volatility of economic fundamentals can affect some asset classes negatively and some positively. Hence, there is no clear direction of how asset prices will move if interventions by central banks reduce or increase volatility. We measure the volatility spillovers from the monetary polices of the Fed and ECB by the amount of volatility in emerging market economies we can explain by the excess volatility

in the Fed and ECB balance sheet.

Relevant empirical literature includes a paper by Izquierdo, Romero-Aguilar and Talvi (2008), which investigates the role of external factors using a VAR/VECM econometric methodology, on the economic performance of Latin America. The authors investigate how external factors contributed to the economic situation in Latin America. More recent literature related to the crisis has focused mainly on event studies looking at the immediate impact of unconventional monetary policy announcements on financial variables. One such paper is by Ait-Sahalia et al. (2012), which utilises an event study approach to explore the market responses to policy initiatives. Moreover, Fratzscher, Lo Duca and Straub (2013), demonstrate how monetary policies pursued by the Federal Reserve, have contributed to portfolio rebalancing and to changing the price of risk in global financial markets. Our paper focuses on measuring the volatility in emerging market economies variables that can be explained by the excess volatility in the volume of assets in the Fed and ECB balance sheet.

A closely related paper by Chen et al. (2013), explores the international spillover of central banks' balance sheet policies. The paper performs an event study as a first step and then uses a Global VAR and a GVECM estimation to assess the international transmission of the expansion of central banks' balance sheets on the financial and real variables in several countries. However, it is not clear that the VECM is the appropriate or the best methodology to utilize, given the criticism of the tests for co-integration by Elliott (1998). Moreover, the dataset used covers the period until 2010 before the crisis had developed in Europe. Additionally, a policy paper by Cecioni, Ferrero and Secchi (2011), provides a useful review of the literature on unconventional monetary policy developed during the recent crisis. We use the latest available data to explore the volatility spillovers from the Fed and the ECB to emerging market economies.

Our paper follows the methodology developed by Ng (2000), who proposed a two step approach to investigating the volatility spillover from the U.S. and Japanese stock markets to the Asia Pacific-Basin region stock markets. The two step approach starts with the calculation of the volatility in a bivariate GARCH model including the U.S. and Japanese stock markets. In the second step it includes the innovations derived in the first step to calculate the volatility spillover to the Asia Pacific-Basin region. The Ng (2000) is not the first paper to explore the volatility spillovers and previous literature has focused also on volatility spillovers such as the Bekaert and Harvey (1997), which allow for an impact, or spillover, of global shocks to the other countries. More recently, Engle, Gallo and Velucchi (2012) find that a network of interdependencies propagates volatility shocks across Asia, which make the system more unstable during crisis. We use the methodology of Ng (2000) and adapt it to explore the volatility spillovers from the Fed and ECB to emerging market economies financial and macroeconomic variables.

Moreover, Hattori, Schrimpf and Sushko (2013) find that perceived risks decrease in response to both announcements and actual unconventional monetary policies by the Fed. More impor-

tantly for our estimations, Hattori, Schrimpf and Sushko (2013) find that the effect of the actual purchases of assets, the increase in the size of the Fed balance sheet, is strongest when there is an expansion and a duration extension of the balance sheet. Bekaert, Hoerova and Lo Duca (2010) find similar results to Hattori, Schrimpf and Sushko (2013), that loose monetary policy decreases risk aversion and uncertainty when they control for business cycle movements. Their results reinforce our empirical strategy, which investigates the volatility of both financial and macro variables, building on the changes in risk aversion and uncertainty generated by the monetary policies of the Fed and the ECB.

In addition, Gambacorta, Hofmann and Peersman (2012) using a Panel VAR approach find that the effects of unconventional monetary policies in different countries contribute to a temporary rise in economic activity and the price level. Therefore, the monetary policy tools utilized by the Fed and the ECB are likely to have temporary positive effects on their domestic economies but are likely to have asymmetric effects on developing countries that do not share the same macroeconomic characteristics. The volatility spillover literature, such Diebold and Yilmaz (2009), has concentrated on stock market returns, and finds that there are bursts to volatility spillovers, that have no trend. This reinforces our findings that the burst in unconventional monetary policies by the Fed and the ECB had an asymmetric impact on the financial and macroeconomic variables in emerging market economies. Yilmaz (2010), calculates an equity volatility spillover index and finds that the interdependence among East Asian equity markets pushed the indices to their highest levels during the current crisis.

The ARCH model was developed by Engle (1982) and Bollerslev (1986) provide a good fit for financial time series. Several volatility models have been proposed, and the GARCH specification has become an important tool in measuring volatility of various financial and economic variables. We use the GARCH model to estimate the volatility of balance sheet of central banks, which has increased significantly since the crisis. The GARCH model is a good fit for both the central bank balance sheets and some of the financial and macroeconomic variables in emerging market economies

Given the above mentioned literature, more rigorous research is needed to evaluate the impact of unconventional monetary policies by assessing their impact on both financial and real variables in emerging market economies. Moreover, more up-to-date data and recent actions by the Fed and the ECB are likely to have impacted emerging market economies in ways unlike previous policies. A suitable methodology is needed to assess the impact of these unconventional monetary policies on the volatility of macroeconomic variables in emerging market economies, such as a GARCH approach. Our research project aims to provide some insights into the effects of exit from unconventional measures as the balance sheet of the Fed slowly decreases in size and the ECB expands dramatically.

3 Theoretical underpinnings and quantitative evidence

The theoretical underpinnings of our empirical specification are based on the effect of changes in the volatility of interest rates in emerging markets, sometimes due to shocks from foreign monetary policy, and their effect on macroeconomic and financial variables as shown by Fernández-Villaverde et al. (2011). The authors build a dynamic stochastic general equilibrium model and find that an increase in real interest rate volatility leads to a decrease in output, consumption, investment, and hours worked when calibrated with data from emerging market economies. These effects are slightly different of the transmission of monetary shock in *levels* of the basic IS/LM model interpreted by Burda and Wyplosz (2012), as the IS/TR model with the Taylor Rule (TR) guiding monetary policy and an international market interest rate.[2] The results of Fernández-Villaverde et al. (2011) are more relevant to our empirical specification because our emphasis is on the measurement of volatility spillover from the Fed and the ECB to emerging market economies. Our goal is to measure the volatility spillover from the Fed and ECB unconventional monetary policies to emerging market economies as the amount of volatility of emerging market financial and macroeconomic variables that can be explained by these monetary policies. The detrimental effects of volatility in interest rates to macroeconomic variables are distinct from the *level* effects and volatility can be detrimental even if the level of interest rate is beneficial for the domestic economy.

Fernández-Villaverde et al. (2011) find that the changing volatility of the real interest rate has significant real effects on emerging market economies. The authors argue that the real effects caused by the volatility are due to households changing their precautionary holdings of foreign debt responding to changes in volatility. The dominant role of the U.S. dollar and Euro denominated assets in the portfolios of international investors and the unconventional monetary policies of the Fed and ECB, which had an effect on the volatility of these assets, are likely to have spillovers to emerging market economies variables. We explore this mechanism to measure the volatility in emerging market economies financial and macroeconomic variables that can be attributed to the unconventional monetary policies of the Fed and the ECB. We use the excess volatility of the balance sheet of the Fed and the ECB to capture the volatility spillover to emerging market economies.

Uribe and Yue (2006) find that interest rate shocks emanating from the U.S. contribute to aggregate volatility in emerging market economies. We build on their results and follow a two step specification to identify the shocks emanating from the Fed and the ECB unconventional monetary policies and test if these shocks have an effect on emerging market economies financial and macroeconomic variables. We then calculate the ratio of how much of the volatility in emerging market economies variables we can attribute to spillovers from the Fed and ECB policies. Our findings are also consistent with Neumeyer and Perri (2005) who find that the international interest rate amplifies shocks to emerging market economies.

[2] See Appendix A for spillover a la Burda and Wyplosz (2012)

4 Methodology and Data

4.1 Data Description

We gather monthly data from the Fed and the ECB regarding the total size of the assets in their balance sheets from 2003M1 to 2014M12. For developing countries we gather monthly data for Brazil, Russia, India, China, South Africa (BRICS), Poland, Croatia, Hungary, the Czech Republic, Colombia, Chile, Peru and Mexico. For the ECB we explore the volatility spillovers to BRICS and Poland, Croatia, the Czech Republic and Hungary, which are closely connected to the euro area economy. For the Fed we explore the volatility spillovers to BRICS and Colombia, Chile, Peru and Mexico, which are more closely connected to the U.S. economy. We collect data regarding the countries' bilateral exchange rate against the U.S. dollar and the Euro, the main stock market index, EMBI spreads, industrial production and the consumer price index. We use monthly data to be able to capture volatility spillover because over longer periods it is harder to decipher the volatility spillovers.

We collected the data using Haver analytics, which provides seasonal adjustments for most of the variables for the emerging market economies and the FRED Dataset for data regarding the Fed and ECB balance sheets. We calculate the change in the Fed and the ECB balance sheet using asset data provided by the respective central banks in monthly frequencies. We also calculate the change in the financial and macroeconomic variables of the emerging market economies in monthly frequencies.

4.2 Methodology

We use a two-step GARCH specification to assess the impact of monetary policies in developed countries, on emerging market economies. We start with the specification of GARCH(1,1) model for the Central Bank:

$$r_t = \sqrt{\sigma_t^2} z_t \quad z_t \sim D(0,1) \tag{1}$$

where r_t is the percentage change in the Central Bank's balance sheet and D is a distribution with mean 0 and variance 1 and:

$$\sigma_t^2 = \omega + \alpha r_{t-1}^2 + \beta \sigma_{t-1}^2 + \epsilon_t \tag{2}$$

where $\omega > 0$, $\alpha \geq 0$, $\beta > 0$ and $\alpha + \beta < 1$

We use the GARCH (1,1) model as defined by Bollerslev (1987), since during the period of 2003-2014, monetary policy was characterized by periods of calm followed by periods of volatility.[3]

In the second step we take the innovations from our first GARCH (1,1) regression and add it

[3]We use GARCH(1,1) for both the Fed and ECB

as an explanatory variable in the second GARCH(1,1) regression for the variables in developing countries. The specification is as:[4]

$$R_{i,t} = \beta_{i,0} + \beta_i R_{i,t-1} + \gamma_{i,t-1} r_{CB,t-1} + \varepsilon_{i,t} \tag{3}$$

and the variance is defined as:

$$\sigma_t^2 = \omega + \alpha r_{t-1}^2 + \beta \sigma_{t-1}^2 + \epsilon_t \tag{4}$$

where $\omega > 0$, $\alpha \geq 0$, $\beta > 0$ and $\alpha + \beta < 1$, where

$$\varepsilon_{i,t} = e_{i,t} + \phi_{i,t-1} e_{CB,t} \tag{5}$$

The above specification means that we include the innovations from our first step, the central bank GARCH(1,1), to capture its explanatory power with regards to the volatility in the variables of developing countries. The above specification is the general specification but we test each time for the significance of the coefficient of the innovations from the step 1 regression. We use the Wald test to test if the coefficient on the innovations of the central bank change in balance sheet is different from zero. Where we find that these coefficients are not different from zero, then we conclude that there are no volatility spillovers.[5]

Then we find the ratio of the volatility of the variables in the developing countries that is explained by the volatility in the developed countries central banks' balance sheet. We calculate this ratio as:[6]

$$VR_{i,t}^{CB} = \frac{\phi_{i,t}^2 \sigma_{CB,t}^2}{h_{i,t}} \tag{6}$$

The ratio of VR measure the proportion of conditional variance of the developing countries variables is accounted for the change in the central banks' balance sheet. This measure will be our volatility spillover measurement from developed countries central bank's balance sheet volatility to variables in emerging market economies. We will illustrate this volatility spillover using graphs to present our results clearly.

5 Results

5.1 Volatility spillovers to emerging market economies

The Fed monetary policies have a more broad volatility spillover to emerging market economies variables and affect volatility in financial and real variables in emerging market economies. The spillovers from the Fed affect almost all emerging market bilateral exchange rates with the

[4] Following Ng (2000)
[5] We use various specifications using the Wald to determine if there are volatility spillovers
[6] Again from Ng (2000)

Figure 3: FED Spillover coefficient and significance

Fed Coefficient

	ER	Stock	EMBIG	IP	CPI
Brazil	0.122291	-0.283628	0.460919	-0.019542	0.001181
Russia	-0.068634	-0.212425	0.986559	0.041721	0.004323
India	0.089247	-0.21423		0.016349	0.005276
China	-0.002652	-0.330518	1.140765	-0.002252	0.003465
South Africa	0.233808	-0.229342	1.241993	0.11947	0.003102
Colombia	0.084933	-0.264605	0.851911	-0.026223	0.001217
Chile	0.234318	-0.108151	0.795969	0.0417	0.001223
Peru	0.026201	-0.428376	1.18434	-0.034249	0.00067
Mexico	0.284748	-0.174538	0.378529	0.00117	-0.000707

Note: Highlighted in green denotes significant coefficients and thus volatility spillovers from the Fed

U.S. dollar, their stock markets and EMBIG spread volatility. Figure 3 shows that there are more volatility spillovers from the Fed's policies to variables in emerging market economies than from the ECB policy. The U.S. monetary policy, because of the dominant role of the U.S. dollar in international financial markets and in trade, has a broader impact and affects more emerging market economies and more of their variables. The impact of the Fed volatility spillovers measured by the 'spillover' coefficient, highlighted in green in Figure 3, is in general larger than the volatility spillovers of the ECB, measured by the coefficient highlighted in green in Figure 4.

The results confirm our intuition regarding the volatility spillovers from the changes in the ECB assets. We find that the volatility spillover from the changes in the ECB assets mainly affects the financial variables in emerging market economies and the spillovers are less pronounced than those of the Fed. Figure 4 summarizes the coefficients of the spillover from the monetary policies of the ECB. We observe that the volatility spillover from the ECB affects mostly EMBIG spreads of emerging market economies and to a lesser extent bilateral exchange rates between the euro and the currencies of emerging market economies.

5.2 Fed Volatility Spillovers

We present the results for the volatility spillovers of the Fed in charts, in logarithmic scale, in order to better illustrate the magnitude of the spillovers. We find that a portion of the volatility in emerging market economies financial and macroeconomic variables can be explained by the volatility spillover from the Fed. Figure 5 shows that the volatility spillover emanating from the Fed extends to almost all emerging market countries bilateral exchange rate with the U.S. dollar

Figure 4: ECB Spillover coefficient and significance

ECB Coefficient

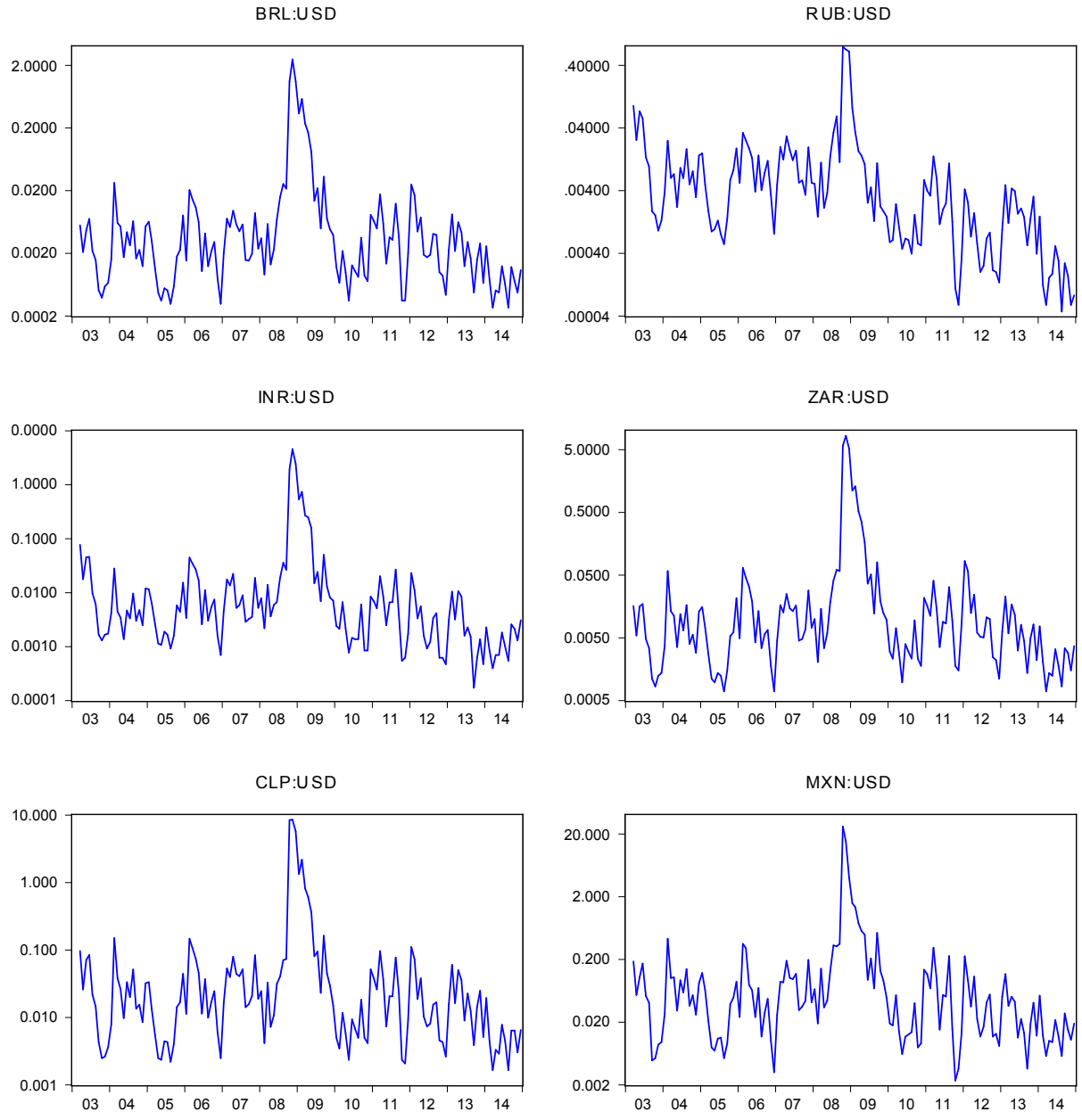
	ER	Stock	EMBIG	IP	CPI
Brazil	0.074285	-0.292549	0.230234	-0.033453	-0.001156
Russia	0.052727	-0.066374	0.923133	0.014517	-0.001122
India	-0.051715	-0.179354		-0.022348	-0.004778
China	-0.090285	-0.66338	1.120844	-0.000554	0.006563
South Africa	0.026056	-0.182408	1.018229	-0.015147	-0.006397
Poland	0.084298	-0.326917	1.605738	0.009562	0.000512
Hungary	0.017565	-0.380366	2.265995	0.012165	-0.012038
Croatia	-0.005042	-0.09759	-0.003938	0.09421	0.002604
Czech Rep.	0.035351	-0.169788		-0.054744	0.001199

Note: Highlighted in green denotes significant coefficients and thus volatility spillovers from the ECB

we investigate. The spillovers are quite large especially around the Lehman Brothers crisis in 2008, where the Fed intervened and drastically increased the size of its balance sheet. We find that during the end of 2008 the volatility spillover from the Fed is higher than the expected volatiliy of the variables. There are other factors that dampen the volatility in emerging market economies and therefore the volatility of their financial and macroeconomic variables is lower than the spillover from the Fed. We do not find volatility spillovers from the Fed to the Renminbi and U.S. dollar exchange rate since the nominal exchange rate between the U.S. and China remains pretty stable during the crisis. Since capital flows into China face restrictions, it is not surprising that we do not find volatility spillovers from the Fed to the Renminbi, U.S. dollar exchange rate.

Figure 6 shows that the Fed had significant volatility spillovers to stock markets in emerging market economies. The volatility spillover again concentrated at the end of 2008 and has since diminished significantly. The volatility spillover from the Fed has decreased even though it had continued to accumulate assets through the end of 2014, which suggests that volatility spillovers to emerging market economies were more pronounced during the crisis of 2008. Further rounds of quantitative easing from the Fed had smaller volatility spillovers than the increases in its assets during the most intense period of the crisis in the end of 2008 and this coincides with the increasing communication or 'telegraphing' of the Fed's subsequent asset purchases. The unexpected nature of the Fed's asset purchases have probably contributed to the magnitude of volatility spillovers to emerging market economies. This was also the case when the Fed announced its 'tapering' of asset purchases, where the initial reaction was sharp but the slow pace and extended communication of the Fed helped to reduce volatility spillovers to emerging

Figure 5: FED Asset volatility spillover to EME Bilateral Exchange Rate



Source: Authors calculations of the volatility spillover to U.S. dollar exchange rates

market economies.

Figure 7 shows that volatility spillovers from the Fed to the EMBIG spreads emerging market economies has been significant and broad. Volatility spillovers emanating from the Fed to emerging market economies borrowing costs were both large in magnitude and broad, affecting all countries in our sample. The volatility spillover from the Fed to emerging market borrowing costs is to be expected given the dominant role of the U.S. dollar in financial markets and especially since much of the emerging market borrowing is carried out in U.S. dollars. Again we observe a spike in volatility spillover from the Fed to emerging market economies borrowing costs in late 2008 and diminishing in later years. Borrowing costs for all emerging market economies in our sample have been affected by the volatility spillovers from Fed and it is reasonable to expect that a sharp decrease in the assets of the Fed would also lead to increase volatility spillovers to emerging market economies borrowing costs.

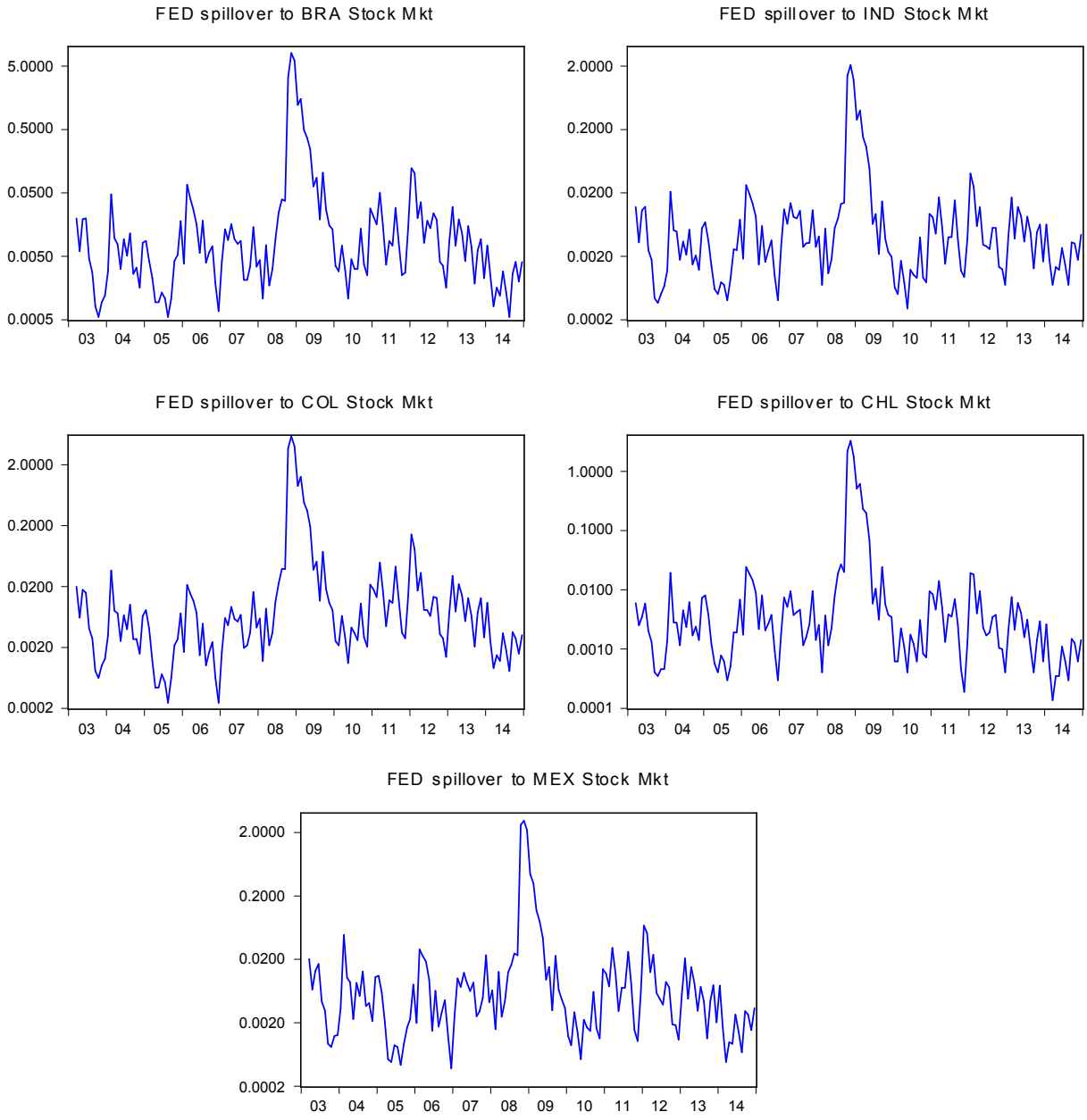
Figure 8 shows that the Fed also had some impact on the volatility of the industrial production in Brazil and Russia. Nevertheless, the volatility spillover from the Fed on industrial production was much smaller the volatility spillover to financial variables. Both Russia and Brazil are commodity exporters primarily invoiced in U.S. dollar, therefore U.S. monetary policy has important effects on their prices and international trade. Again we do not find that China was affected by volatility spillovers probably because capital inflows into China face significant restrictions and had little effect on the Chinese nominal exchange rate.

During the peak of the crisis in late 2008 and the beginning of 2009 the volatility spillover from the Fed to the emerging market economies was much higher. During that time the Fed increased its balance sheet significantly to stop the panic in the U.S. financial system by aggressive accumulating assets. The Fed introduced a range of measures including the Term Auction Facility (TAF), Dollar Swap Lines, Term Securities Lending Facility (TSLF), Primary Dealer Credit Facility (PDCF), Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF or ABCP MMMF), Commercial Paper Funding Facility (CPFF) and Term Asset-Backed Securities Loan Facility (TALF). Countries with more open capital accounts seem to be the ones experiencing the highest volatility spillover from the expansion in the Fed's balance sheet to their economies. We can also observe that generally the Fed volatility spillovers were limited to 2008-9 and have since generally decreased in magnitude even during the tapering period. Perhaps the enhanced guidance and steady approach to changes in the Fed balance sheet have diminished volatility spillovers from the Fed.

5.3 ECB Volatility Spillovers

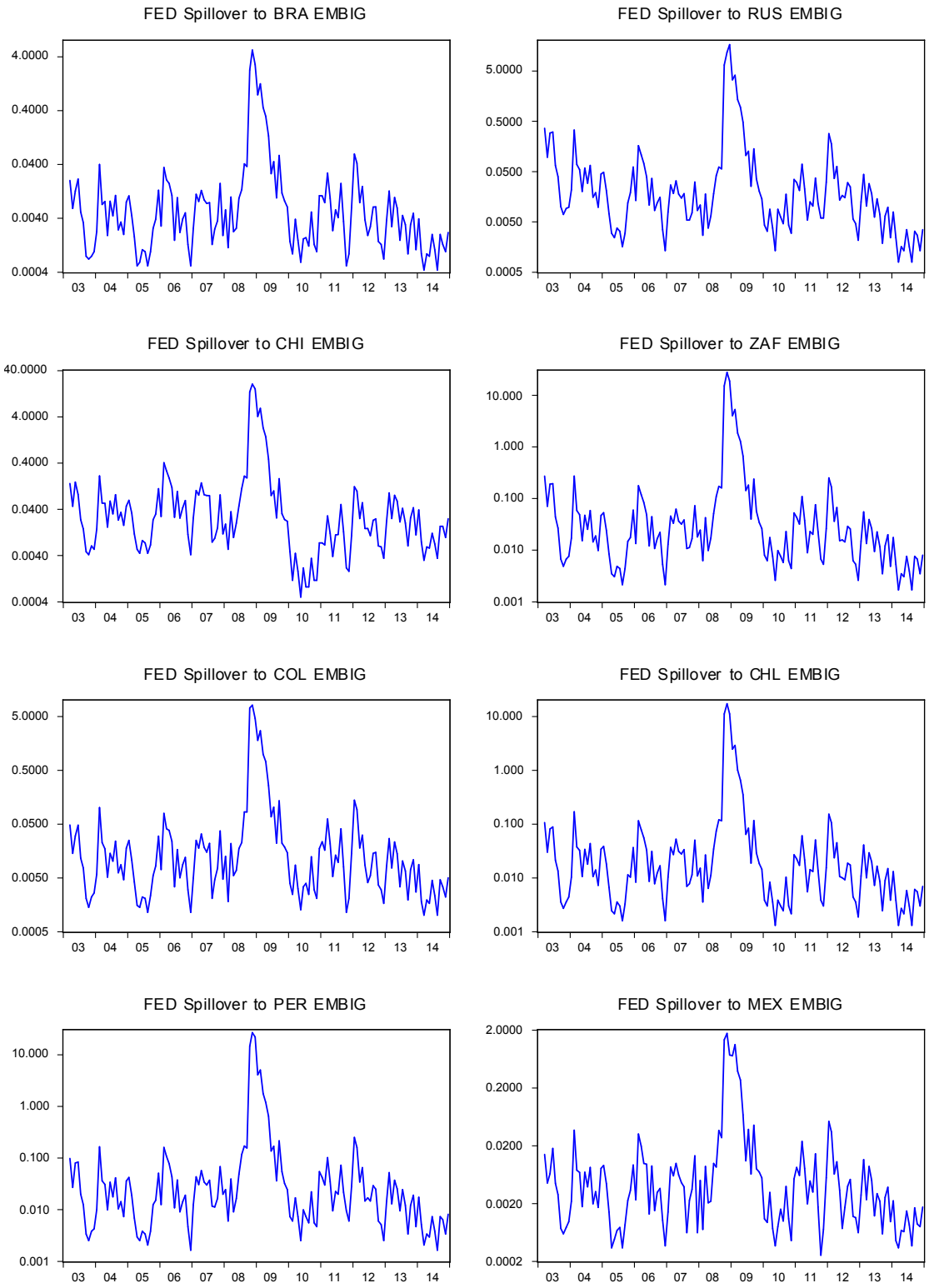
We present the results for the volatility spillovers of the ECB in charts, in logarithmic scale as we did for the Fed, in order to better illustrate the magnitude of the spillovers. We find that a portion of the volatility in emerging market economies financial and macroeconomic variables can be explained by the volatility spillover from the ECB. Figure 9 shows that a significant

Figure 6: FED Asset volatility spillover to EME Stock Markets



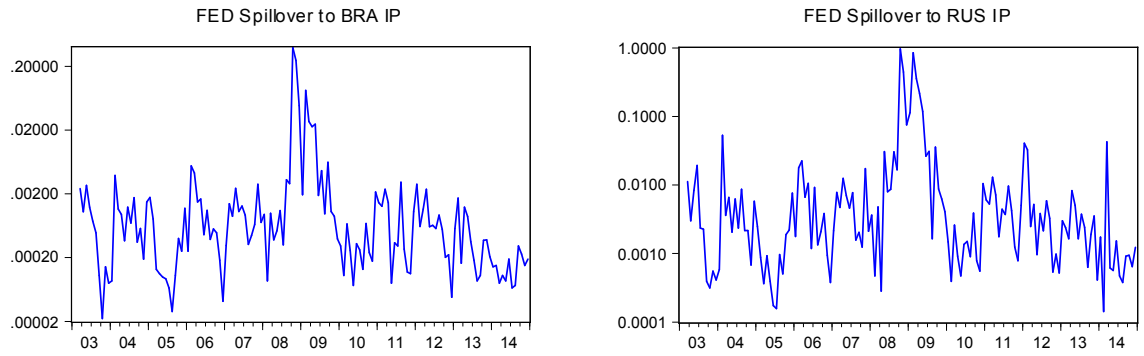
Source: Authors calculations of the volatility spillover to stock markets in EME

Figure 7: FED Asset volatility spillover to EME EMBIG



Source: Authors calculations of the volatility spillover to EME borrowing costs

Figure 8: FED Asset volatility spillover to EME IP



Source: Authors calculations of the volatility spillover to industrial production in EME

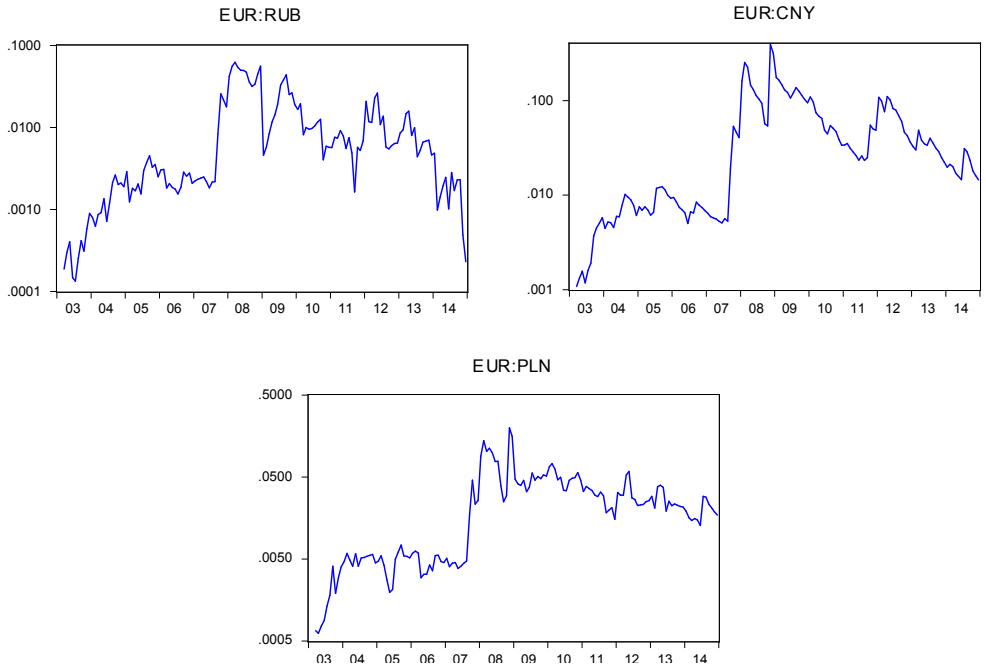
portion of the volatility of the bilateral exchange rate between the Russian Ruble, the Chinese Renminbi, the Polish Zloty and the Euro is due to volatility spillovers from the ECB. The volatility spillover emanating from the ECB to the bilateral exchange rate with Russia is much lower than the volatility spillover from the Fed on the bilateral exchange rate of the U.S. with Russia. Similar to the Fed spillover, the ECB volatility spillover is concentrated in the period of the end-2008.

Next we looked at the effect the volatility spillover from ECB to the stock markets in emerging market economies. Figure 10 shows significant spillovers to the Brazilian, Polish and Hungarian stock markets. The spillovers from the ECB again have peaked towards the end of 2008 but still remain significant for these countries since the ECB balance sheet size has fluctuated. The Hungarian stock market is the most vulnerable to volatility spillover from the ECB but even there the spillover has diminished since 2009. The ECB volatility spillover is less broad than the spillover from the Fed due to the secondary role of the euro in financial markets.

Figure 11 shows that ECB had significant spillover on emerging market economies borrowing costs. As measured by EMBIG, borrowing costs in Russia, China, South Africa, Poland and Hungary were affected by volatility spillovers from the ECB. Again the spikes in volatility spillovers occur at the end of 2008 and diminish later. However, for Hungary volatility spillovers from the ECB remained high until the end of 2014. It is likely that emerging market economies in eastern Europe, which are closely interconnected with the euro area economy, would face more volatility spillovers as the ECB embarks on its own programme of quantitative easing in March, 2015. The ECB plans to expand its balance sheet by buying euro denominated assets quite aggressively and this is likely to lead to volatility spillovers to emerging market economies especially in eastern Europe.

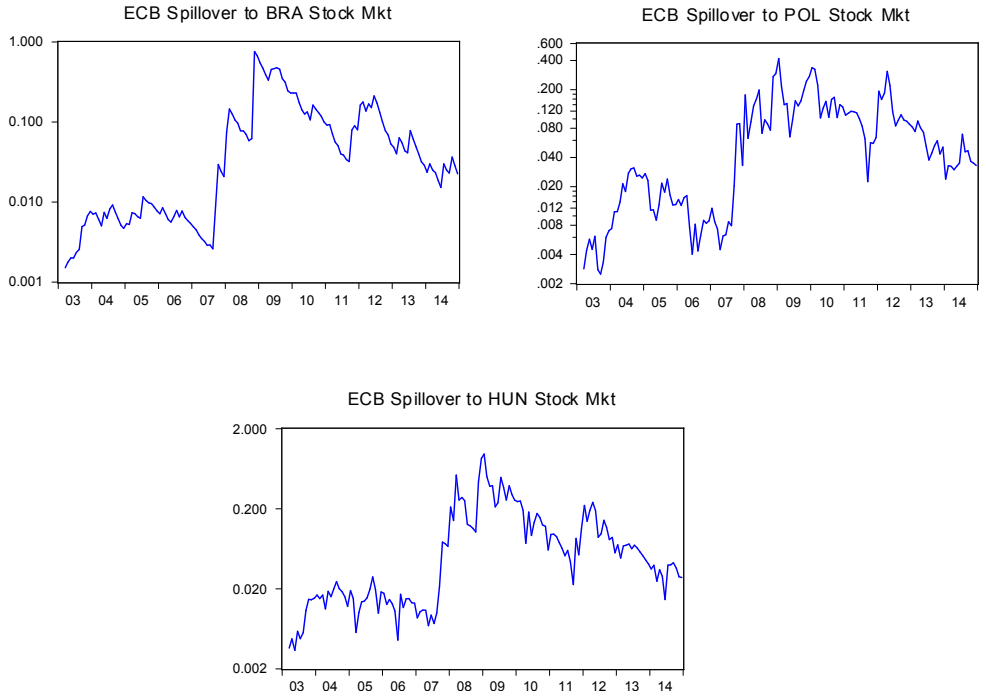
Our findings have important implications when we consider that the Fed has stopped expanding its balance sheet while the ECB is embarking on a substantial increase of its own. The ECB

Figure 9: ECB Balance Sheet volatility spillover to EME Exchange Rates



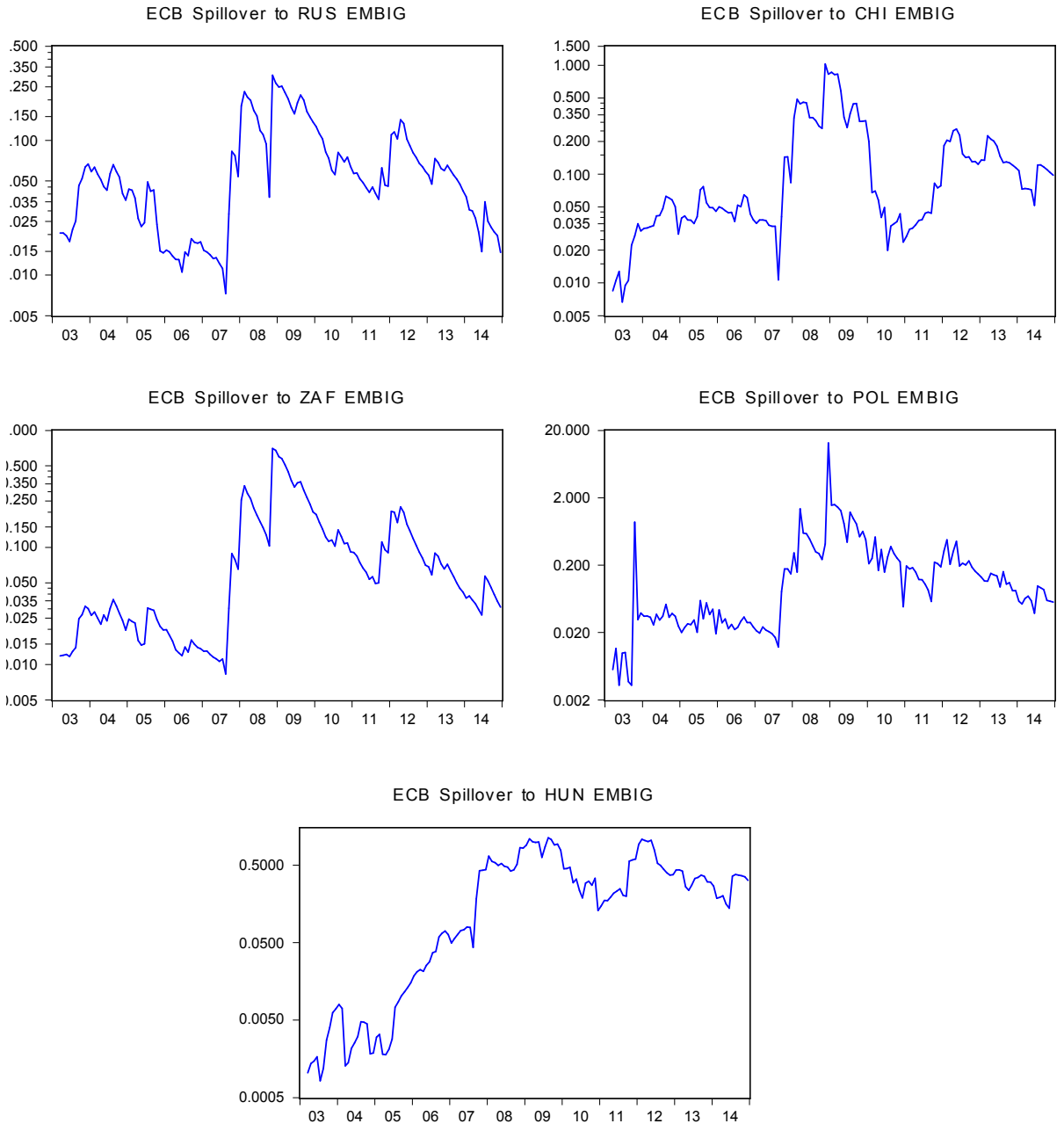
Source: Authors calculations of the volatility spillover to euro exchange rate

Figure 10: ECB Balance Sheet volatility spillover to EME Stock Markets



Source: Authors calculations of the volatility spillover to stock market in EME

Figure 11: ECB Balance Sheet volatility spillover to EME EMBIG



Source: Authors calculations of the volatility spillover to borrowing costs in EME

volatility spillovers have not diminished as much as the Fed volatility spillovers since the 2008-9 perhaps reflecting the ongoing euro area crisis and the related changes in the ECB balance sheet. Notwithstanding the end of the Fed's quantitative easing programme in 2014 and the expected policy tightening by the end of 2015, overall monetary conditions in the two most important central banks in the world are likely to remain looses and continue sending volatility spillovers to emerging market economies.

6 Policy Implications

The policy implications from our paper are three-fold: First, the monetary policies pursued by central banks are likely to have had an impact on different variables in emerging market economies but the volatility spillovers from the Fed have had much far reaching effects on emerging market economies than those of the ECB. Second, the most affected countries in general have been the ones who have had a more open capital account and greater financial linkages with the U.S. and euro area economies. Third, the impact of exit from unconventional monetary policies, is likely to affect the volatility of emerging market economies if it is not done gradually. Most emerging market economies have weathered the crisis well, and have been able to absorb the volatility coming from developed countries central banks. Given the slowing growth and other problems observed in the emerging market economies, the volatility spillovers from the end of loose monetary policies in the U.S. and the beginning of looser monetary policy in the euro area are likely to be large.

As a result, emerging market economies should stand ready to limit volatility spillovers that are likely to come from the unwinding of the unconventional monetary policies by the Fed and the commencement of quantitative easing by the ECB. Measures to limit volatility spillover by emerging market economies may include but not limited to increasing interest rates, minimizing the volatility of exchange rates with official intervention, close monitoring of stock market volatility and being able to withstand volatility in lending and borrowing rates with additional fiscal space. Moreover, where possible, macroprudential policies can be used to this end, as well as targeted capital controls, to help insulate economies from volatility spillovers from abroad.

7 Conclusion

The main contribution of this paper is to present a method for measuring volatility spillovers from the monetary policies of one country to another and to demonstrate that there have been indeed volatility spillovers from the actions of the ECB and the Fed to emerging market economies. On the one hand, the volatility emanating from the ECB is generally less pronounced and on the other hand, the volatility spillovers from the Fed had much more far reaching implications for emerging market economies. We find that the volatility spillover from the Fed and ECB has

been significant.

Despite the recent global financial crisis that slowed global growth and caused severe recessions in many developed countries, emerging market economies in general have been able to grow impressively compared to developed economies. Nevertheless, emerging market economies growth rates have been sluggish in the during the latter part of 2014 and the start of 2015. If this continues and the withdrawal of monetary stimulus or even interest rate increases by the Fed, emerging market economies might not be able to weather a renewed volatility bout of spillover to their economies. Caution is necessary because of the asymmetric monetary policy stances with the ECB loosening monetary policy and the Fed tightening it. This is likely to have an asymmetric effect on the volatility of economic variables in the emerging market economies. This effect might be capital flight affecting financial variables, but also the lack of confidence in the economy which could lead to more pronounced problems in the real economy such as decreases in consumption and investment.

Some important caveats remain in the econometric technique such as the limited amount of years of data about the Fed and the ECB's balance sheet. In the future, when more data are available a more robust specification could be carried out in combination with various GARCH specifications. This further work would build a more complete picture of the volatility spillover from the ECB and the Fed into emerging market economies.

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Appendix A World interest rate, IR/TR and interest rate level spillover

The basic model of IS/TR in an open economy framework is depicted in Figure 3. The world interest rate facing a country is defined as i plus expected depreciation of that currency. This is depicted as the International Financial Market (IFM) line. Normally countries cannot affect the world interest rate but that cannot be said for the Fed and the ECB. The response of the Fed and the ECB, which achieve a reduction in interest rates by expanding their balance sheets, is shown by the movement of the TR to the right at TR'. During the crisis, these the Fed and the ECB lowered their interest rates and embarked on unconventional monetary policies, which in turn lowered the world interest. However, the ECB and the Fed can only lower the world interest rate less than their domestic interest rates and as a result their currencies weakened as well. As a result capital flight from the Eurozone and the U.S. ensued, and capital was directed towards emerging market economies that had a higher interest rate. In reaction, emerging market economies central banks' could have lowered their domestic interest rates, however due to various reasons they were not able to reduce their interest rates as much as the Fed and the ECB. Therefore, to accommodate this influx of capital their economies will have to adjust. IS will shift to IS', unless governments embarked in ambitious fiscal stimulus programs.

Using the Burda and Wyplosz (2012) methodology, Figure 3 demonstrates that unconventional monetary policies emanating from developed countries Central Banks, which have an effect on the world interest rate, can affect both the financial and real variables in emerging market economies. The effects of these unconventional monetary policies are asymmetrical.

Figure 12: Spillover when Central Banks become more accommodative